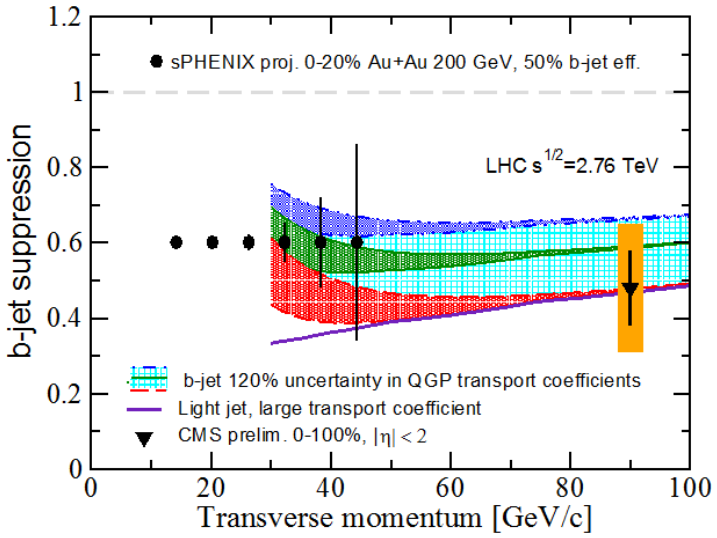
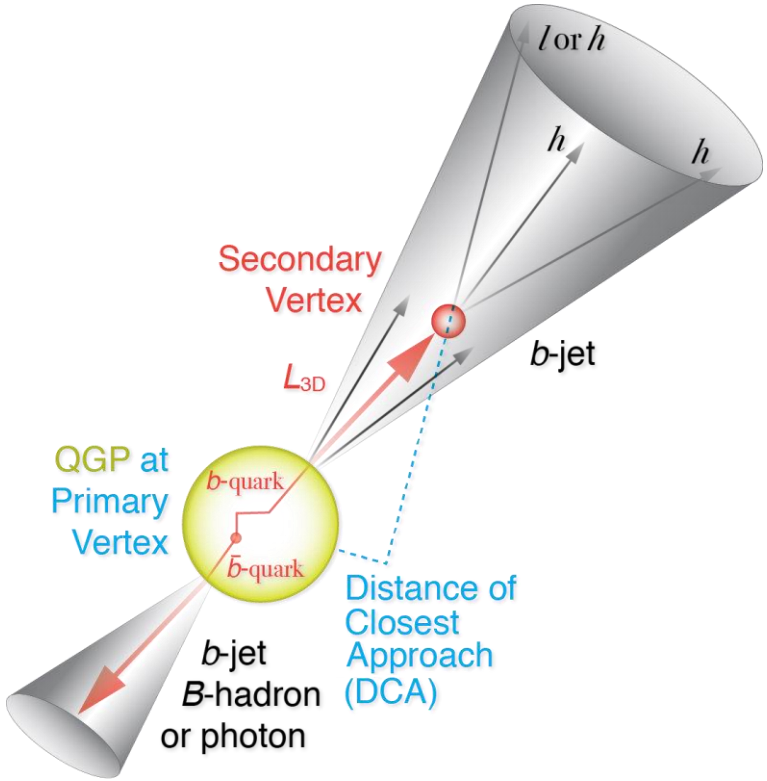
b-tagged jet Topical Group Plan

Jin Huang (BNL)
Mike McCumber (LANL)

PHENIX

Introduction





- HF-jet: in particular *b*-jet, when compared with much more abundant light-parton jet, provide differentiating sensitivity to collision VS radiative energy loss
- Complimentary to current and future RHIC HF-hadron/lepton measurements (see also talk of Ming/Xin): “no” FF complication, probing parton energy and higher-scale
- Detection technique employed: Jet + jet structure information enhancing *B*-hadron fraction, i.e: displaced track, high mass secondary vertex and enhanced leptonic decay products

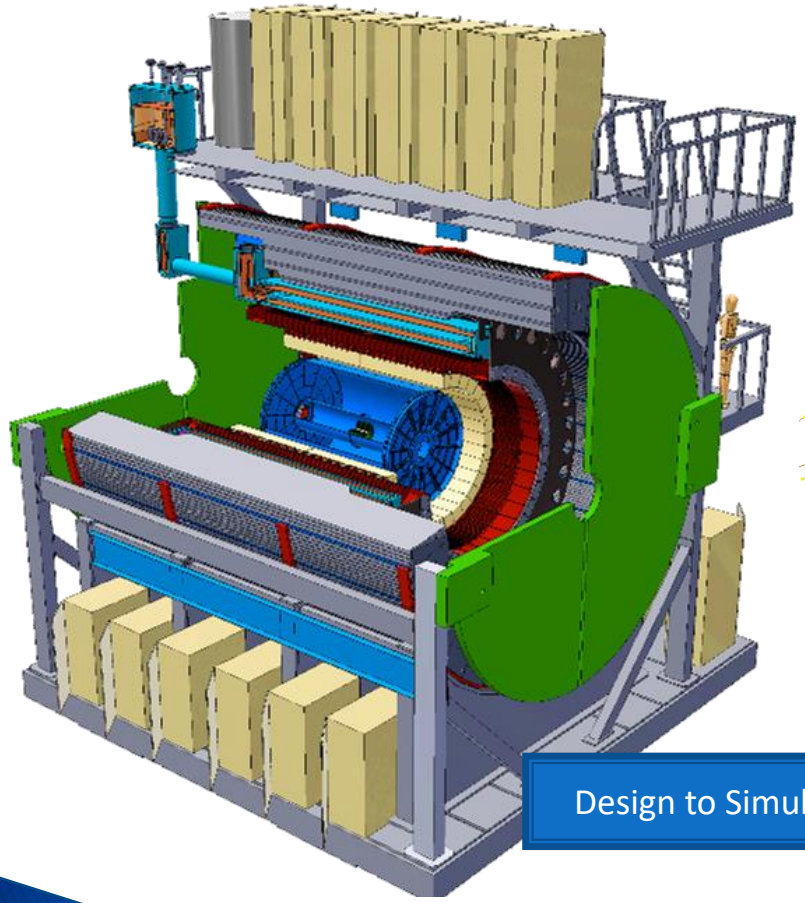
Topical group organization

- Co-conveners
  - Jin Huang (Brookhaven National Lab) <jhuang@bnl.gov>
  - Mike McCumber (Los Alamos National Lab) <mccumber@bnl.gov>

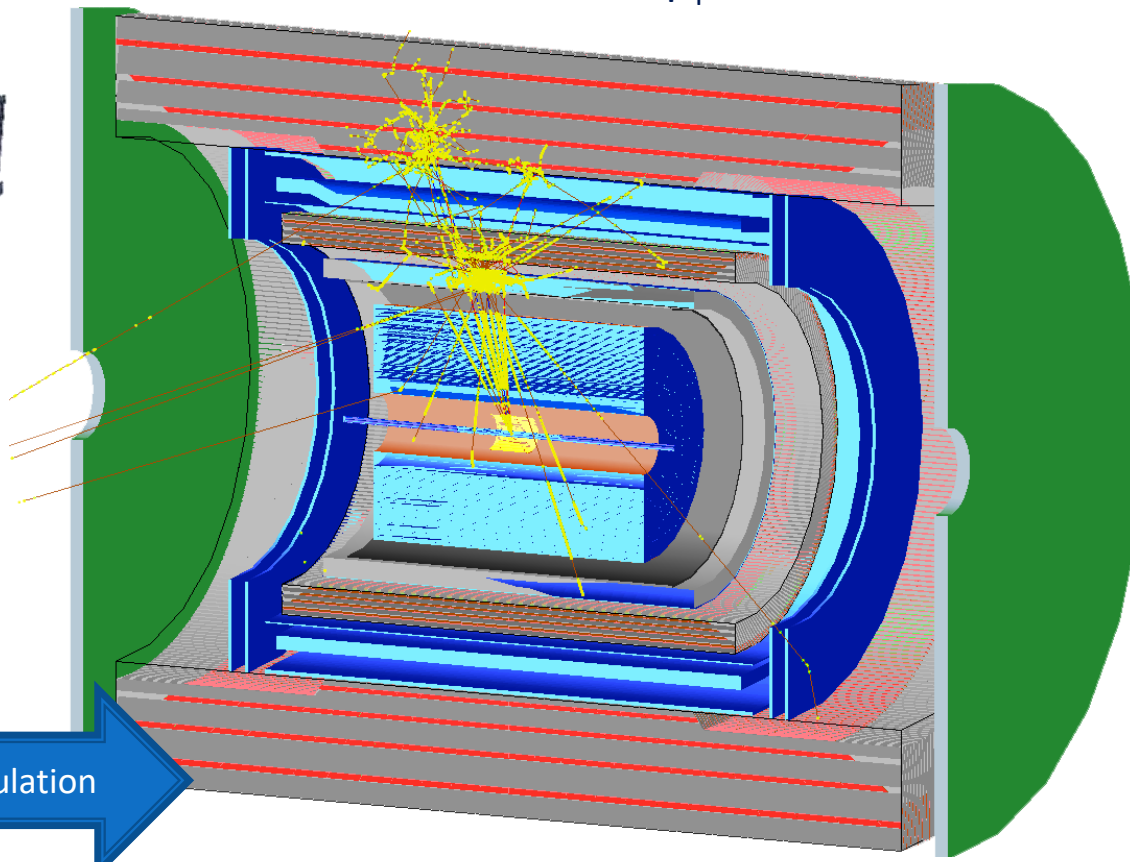
- We are very fortune to have a diligent team working on a wide spectrum of high-priority development
  - More manpower are always welcomed and needed!
- Communication:
  - Discussion email list: https://lists.bnl.gov/mailman/listinfo/sphenix-hf-jets-l
  - Wiki page under construction: https://wiki.bnl.gov/sPHENIX/index.php/Heavy_Flavor_Topical_Group
- Meetings/Events
  - Use weekly simulation meetings for updates, as many high-priority tasks involve software developments with tracking detector designs https://indico.bnl.gov/categoryDisplay.py?categId=88
  - Goal oriented irregular events:
    - Now: MAPS+HF-jet workfest, Jan 5-7 2017 @ Santa Fe https://indico.bnl.gov/conferenceDisplay.py?confId=2641
    - First work-fest on May 16-17
    - Initial TG meeting on Apr 22

b-jet simulations, drawing to Geant4

sPHENIX Geant4 simulation of p_T=30 GeV/c B^+-hadron



Design to Simulation

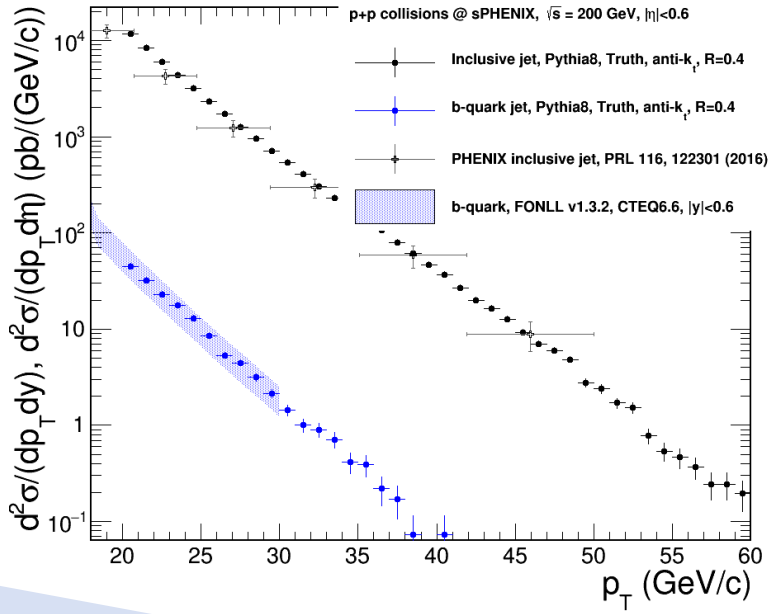


Simulation resources

- Currently we separate jet and b-tagging simulations to help speed up simulation. Need to verify factorization in the next stage
- Simulation setup used in analysis:
  - Tracking simulation in p+p in MAPS+IT+TPC (few minute / event)
  - Tracking simulation in HIJING + embedding for 7-layer MAPS (few minute / event, used for initial tunings) and for MAPS+IT+TPC (1-hour / event, use for performance plots)
- In developments
  - Silicon detectors in ladder geometry <- make available soon?
  - Pile up simulation <- make available soon?
  - TPC distortion corrections

Jet flavor definition tools

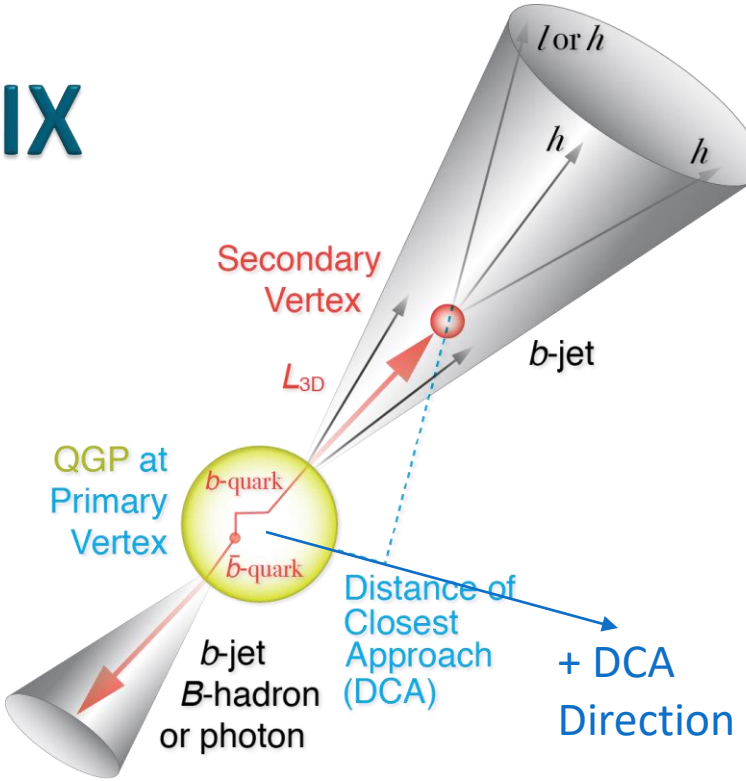
- Unifying truth definition and jet sample generations
  - Based on Dennis' work defining a truth tagging module run on MB events to synchronize *B*-jet definition and yield between analyzers
  - Two options provided in defining truth jet by matching *b*-quark in jet (CMS definition) or by matching *B*-hadron in jet (proposal definition)
  - Available on GitHub: https://github.com/sPHENIX-Collaboration/analysis/tree/master/HF-Jet/TruthGeneration
- In collaboration with TS TG: Plan to be generalized to light-parton tagging and parton interaction channel categorizations
- Mid-term goal: cross checked with data and NLO generators



Tagging *b*-jets in sPHENIX

Exploring three leading methods for sPHENIX *b*-jets identification and crosscheck

- Multiple large DCA tracks
  - Near term goals: 3-Dvertex, HIJING simulation
- Secondary vertex and kinematic fits
  - Near term goals: HIJING simulation
- *B*-meson tagging via semi-leptonic decay or direct invariant mass reconstruction
  - Need



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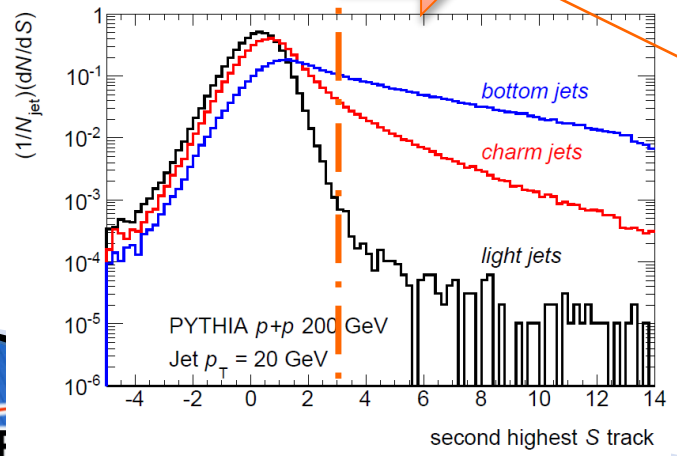
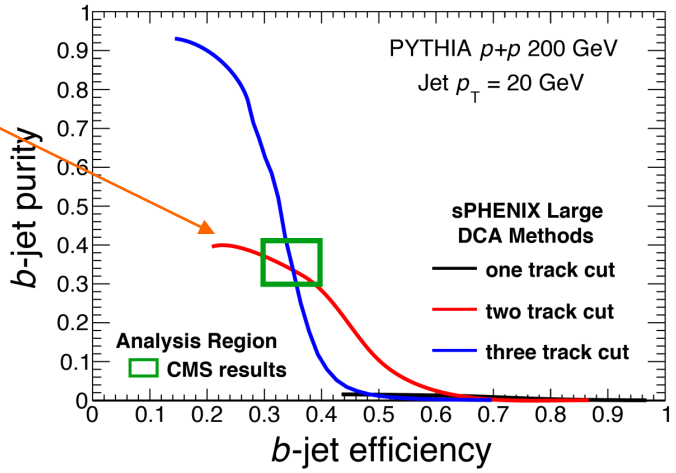
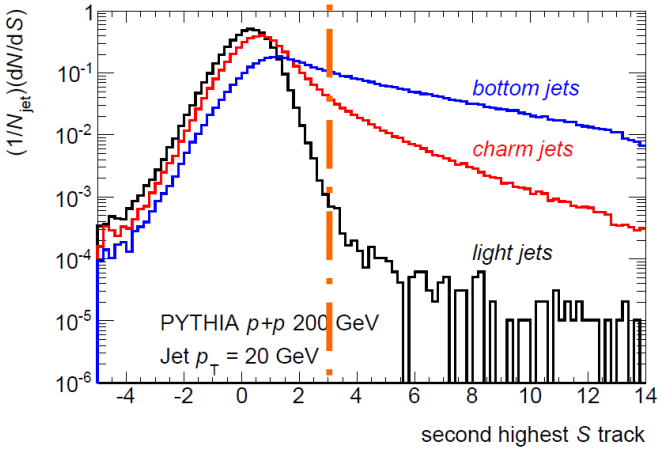


MIE-proposal projection (updated in G4 later slides)

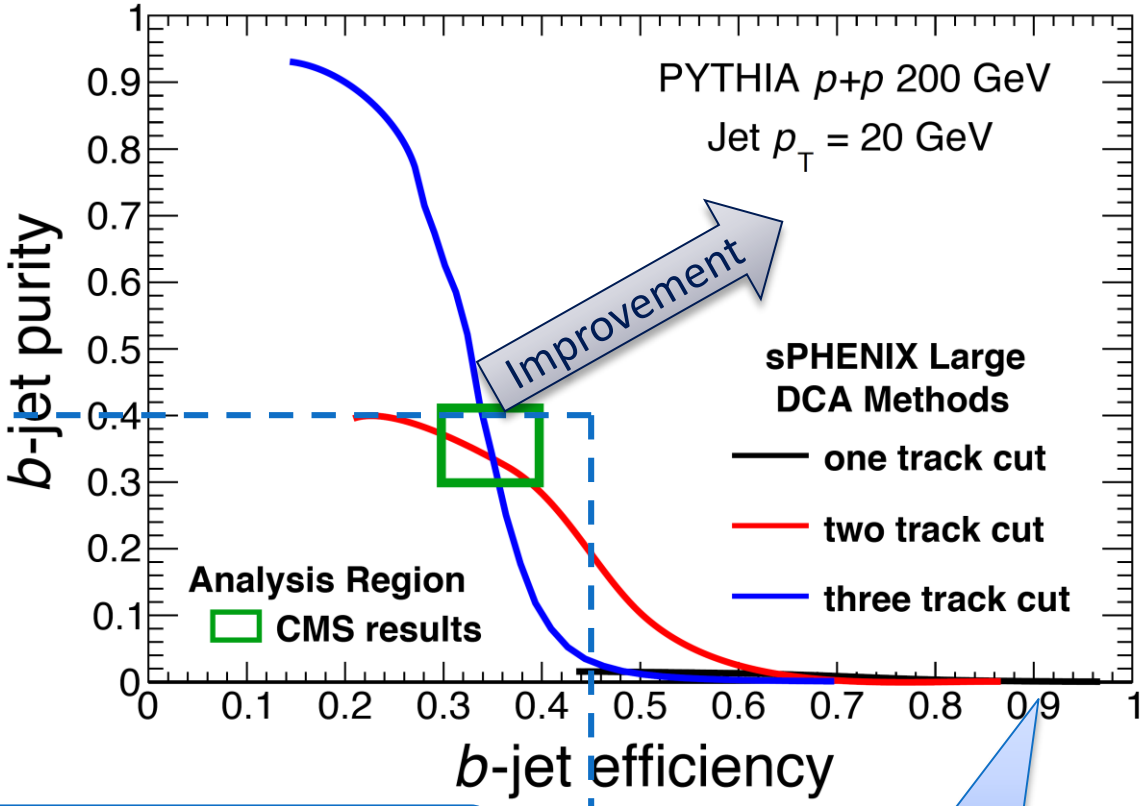


What affects performance curves

Cut



MIE-proposal projection, updated in G4 later



Saturate efficiency at level determined by

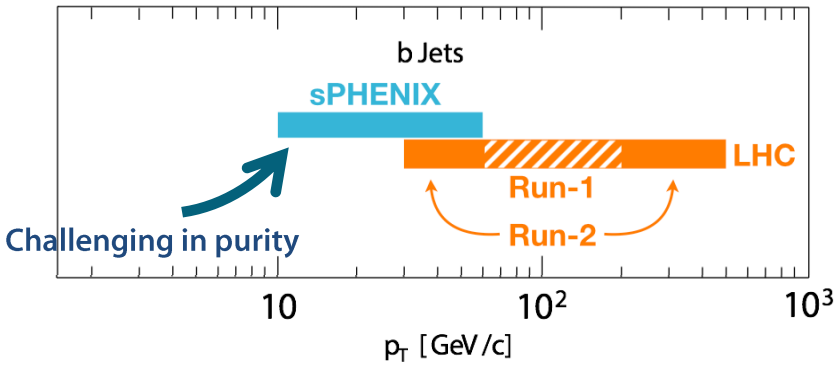
- Control light decay-background
- Fake high DCA (mismatching, alignment) → realistic sim.

Performance turn-on at primary particle's DCA peak
Efficiency improve w/ higher DCA precision from MAPS

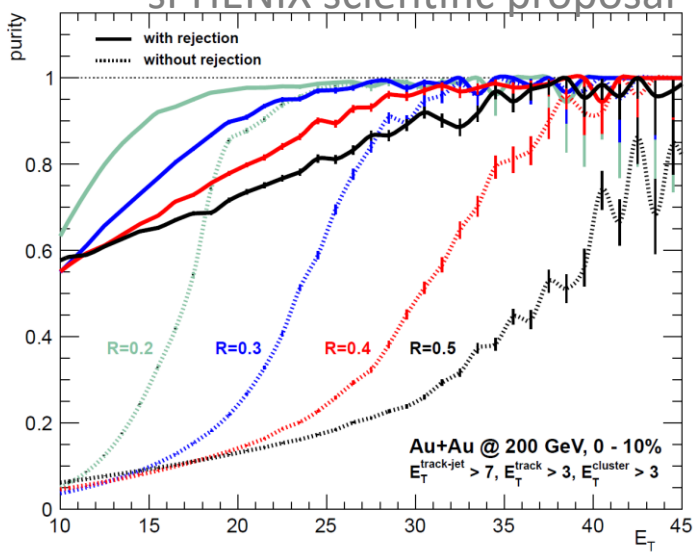
Initial b-jet fraction

Jet finding and fake rejections

- HF-jet are based on jet, relying on jet finding development lead by JS TG
  - Emphasis on purity and reach to lowest-possible-p_T jet, where mass effect is maximized
  - No statistics for *b*-jet beyond $p_T > 50$ GeV/c
- HF-jet specific: response in detector for *b*-favored jet, unfolding and media modification
  - Require join study with JS TG in term of experience and toolkit developments

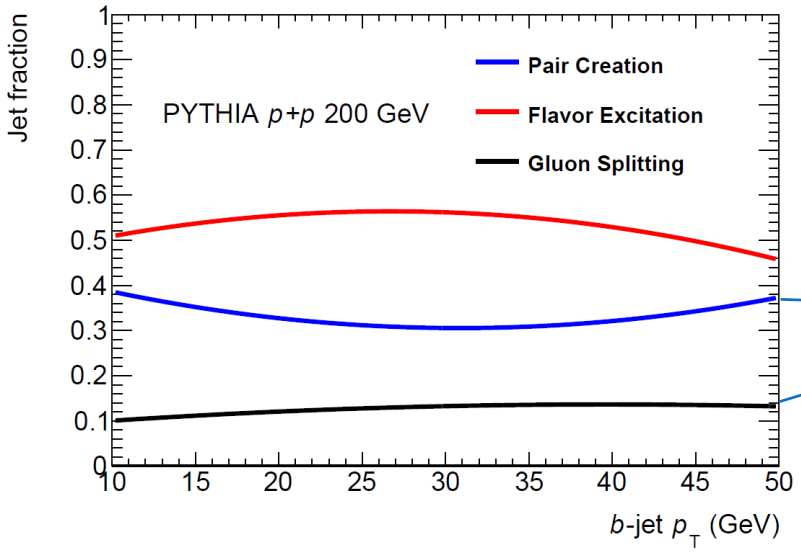


sPHENIX scientific proposal

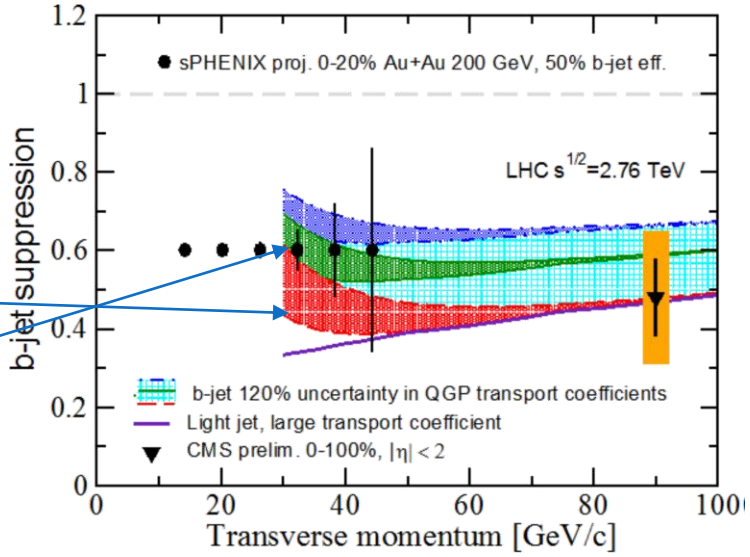


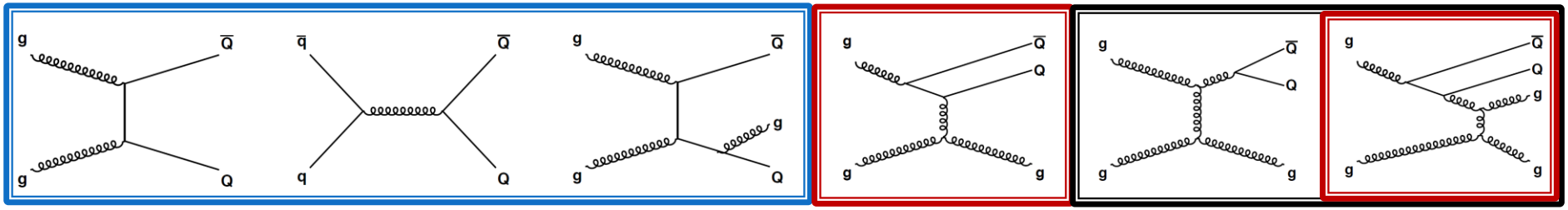
An vulnerability (opportunity) of HF-probes

sPHENIX scientific proposal



CMS, Phys.Rev.Lett. 113 (2014)
Phys.Lett. B726 (2013) 251-256

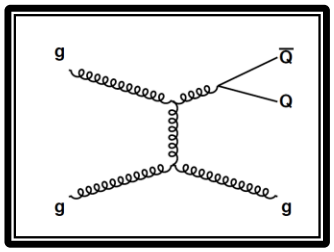


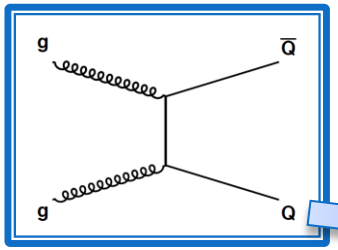


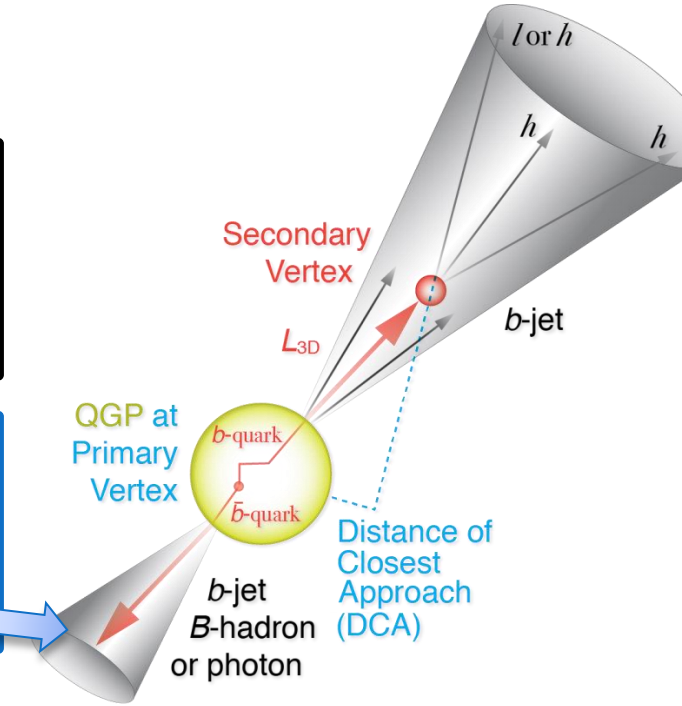
Lund String, Eur. Phys. J. C 17, 137–161 (2000)

b-quark jet selection 1: *b*-jet correlation

- Event topology to select *b*-quark jet
  - *b*-jet in correlation with opposite-going *B*-hadron, *b*-jet and photon
- sPHENIX provides good acceptance on *b-di*-jet and *b*-jet – non-prompt-*D* correlations
- Helps on purity of jet and *b*-tagging too
- Near term goals: fast-sim projection

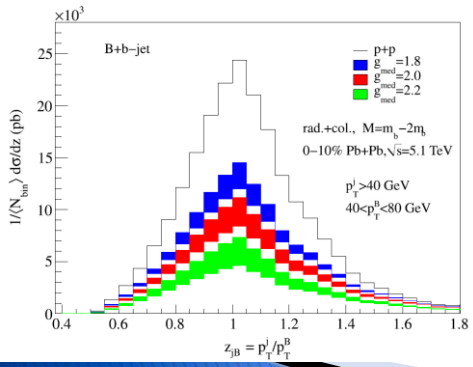






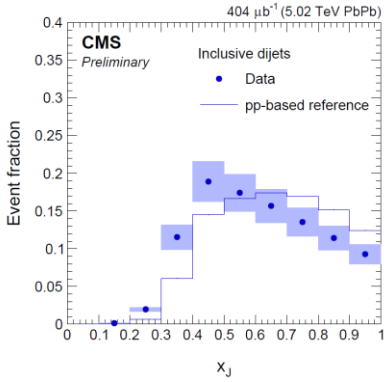
b-jet + *B*-hadron, model

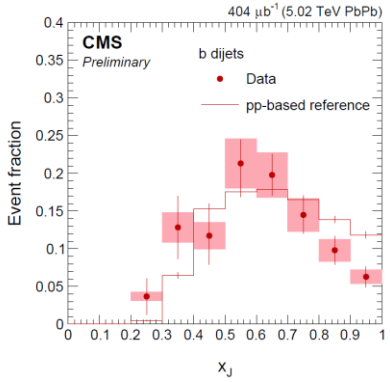
Physics Letters B750 (2015) 287–293



b di-jet, CMS 2016

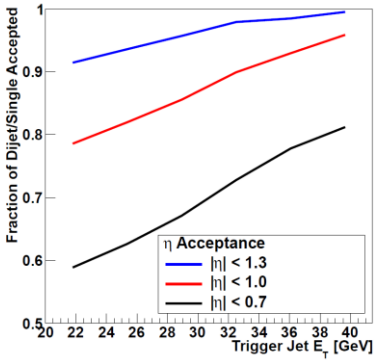
CMS PAS HIN-16-005





di-jet acceptance in sPHENIX

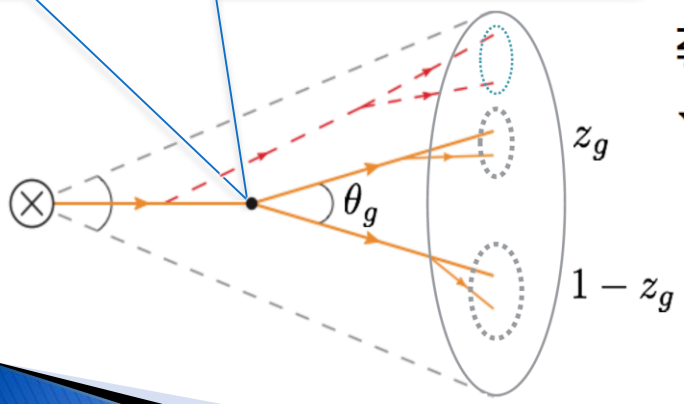
sPHENIX scientific proposal



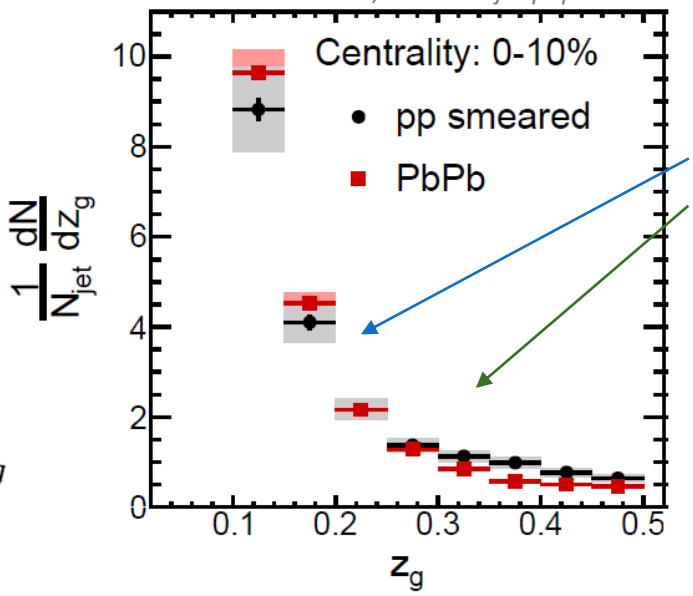
b-quark jet selection 2: Jet structure tools

- Jet structure tool developed in HEP adapted in HI field
- Jet grooming observable z_g to separate *b*-quark jet and $g/q \rightarrow b\bar{b}$ jet?
- Mid-term goals: in collaborate with JS TG in developing grooming tools

Earliest splitting:
More symmetric for $g/q \rightarrow b\bar{b}$ jet?



CMS-PAS-HIN-16-006, inclusive jet *p*+*p* 5.02 TeV



- *b*-quark jets ??
- $g/q \rightarrow b\bar{b}$ jet ??

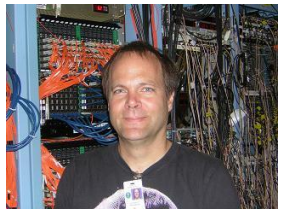
A+A Modification would enhance z_g~0.5 (i.e. $g/q \rightarrow b\bar{b}$ less suppressed)?

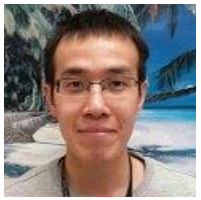
Summary

- High priority development tasks :
  (current developers and your help/ideas welcomed!)
  - Realistic implementation in Geant4
    - Tony F./Gaku M./Chris P.: Near term goal - Validating for general use.
  - Pile up simulation
    - Mike M.: Near term goal - Validating for general use.
  - Generalized Kalman filter
    - Haiwang Y./Chris P., ready, used in analysis, improving details
  - Multi-vertexing/*b*-tagging via secondary vertexing in jet
    - Sanghoon L./Haiwang Y.: ready, used in analysis, Near term goal - HI analysis
  - *b*-jet tagging: Track Counting
    - Haiwang Y./Dennis P.: ready, used in analysis, Near term goal – signed-DCA_3D, HI analysis
  - *b*-jet tagging: Soft Lepton Tagging, exploratory
  - *b*-quark jet selection: B-Meson Tagging. Near term goal – fast-sim projection, volunteers welcomed
- Area of overlapping with to other TG groups
  - JS TG: Jet detection / modern jet structure tools / event and jet flavor tagger
  - Quarkonia TG: tracking development / HF-meson detection

Extra information

HF-jet TG high priority longer-term tasks



- Goal: realistic study of HF jet performance in sPHENIX simulation and reconstruction.
- High priority development tasks :
  (current developers and your help/ideas welcomed!)
  - Realistic implementation in Geant4
    - Tony F./Gaku M./Chris P.: merged to main repository last week. Validating for general use.
  - Generalized Kalman filter
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  - Multi-vertexing/*b*-tagging via secondary vertexing in jet
    - Sanghoon L./Haiwang Y.: ready, used in analysis, push towards HI analysis
  - *b*-jet tagging: Track Counting
    - Haiwang Y./Dennis P.:
      ready, used in analysis, push towards 3-D DCA and HI analysis
  - *b*-jet tagging: Soft Lepton Tagging, exploratory
  - *b*-quark jet selection: *B*-Meson Tagging. Exploratory, volunteers from LANL and LBNL
- Area of overlapping with to other TG groups
  - JS TG: Jet detection / modern jet structure tools / event and jet flavor tagger
  - Quarkonia TG: tracking development/ HF-meson detection

Register today: Workfest

https://indico.bnl.gov/conferenceDisplay.py?ovw=True&confId=2641

MAPS MIE proposal and HF-jet Topical Group Workfest

5-7 January 2017 *Santa Fe, NM*
US/Mountain timezone

Search

Overview
Timetable
Registration
Modify my registration
List of registrants

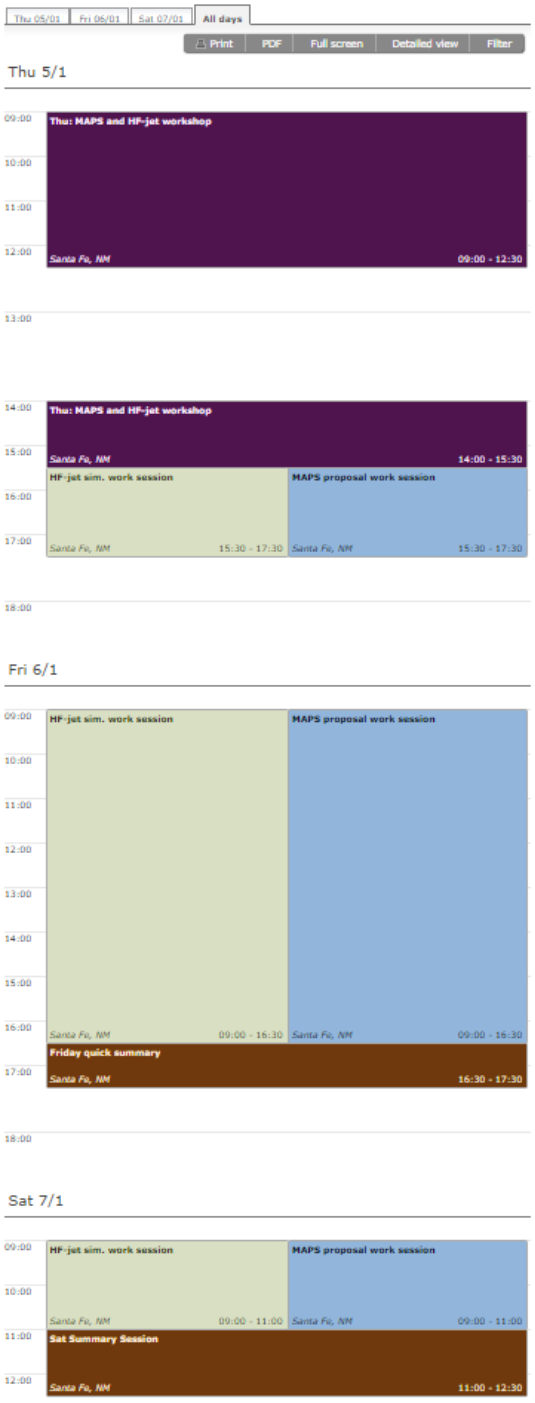
MAPS detector group and HF-jet topical group invites you to this sPHENIX workfest @ Santa Fe, NM. The goals of this workfest are

- MAPS detector group
  - Make significant progress on MAPS MIE proposal
  - Update the cost and schedule to be ready for discussion with DOE in Feb budget meeting
  - Develop additional physics cases for MAPS detector beyond sPHENIX scientific proposal
- HF-jet topical group
  - Produce near final *b*-jet tagging performance plot for MAPS proposal and QM2017 conference
  - Advance the tracking detector simulation towards new baseline simulation configuration
  - Develop B-meson simulations

The workfest is organized as

- Thu Jan 5: workshop style talks summarize current considerations on MAPS detector, HF-jet simulations and new ideas. Bluejean broadcast will available for remote participations.
- Fri Jan 6: parallel work sessions on MAPS proposal and on simulations, with brief summary session at the end of the day.
- Sat Jan 7: parallel work sessions in the morning. Summary session in noon and work sessions in the afternoon.

Dates:	from 05 January 2017 08:00 to 07 January 2017 18:00
Timezone:	US/Mountain
Location:	*Santa Fe, NM* Hotel to be announced
Chairs:	Dr. Liu, Ming Dr. Huang, Jin Dr. McCumber, Michael
Additional info:	***Accommodation*** Local organizers at LANL is arranging for conference hotel with block room and conference setup. Details to be announced.

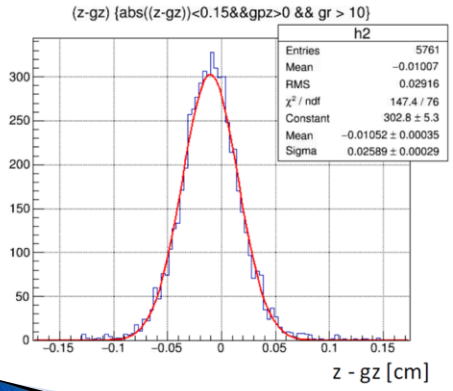


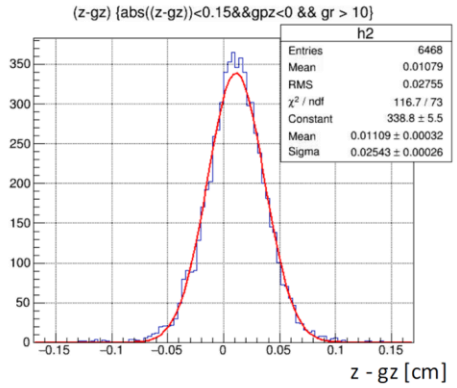
Highlight recent activities: DCA_x

- Both methods highly depending on quality of DCA
- Haiwang *et al* developing capable Kalman filter (GenFit2), expand to DCA_{3D} and use it to validate
- Not only-MAPS matters for DCA
  - Consider use z-sensitive strip in subset layers of INTT?
  - Important to develop and verification as a whole system downstream of clustering

Small (but systematic) bias in TPC cluster z

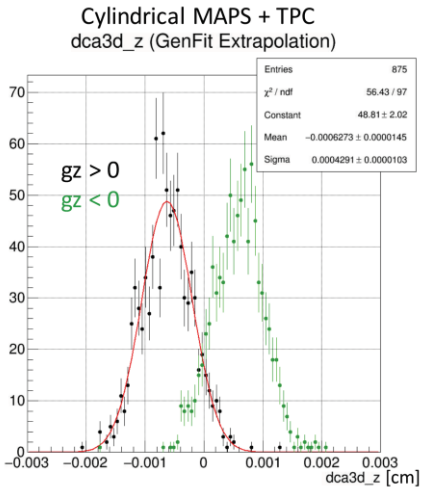
TPC software group is fixing this problem





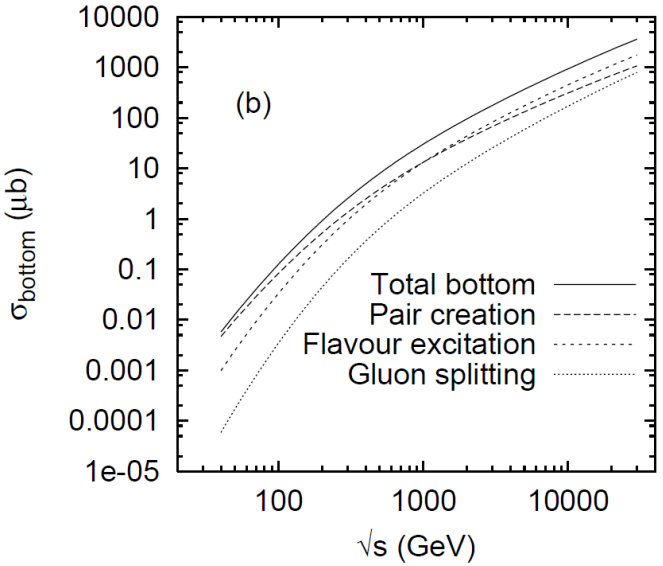
Kalman fit with MAPS

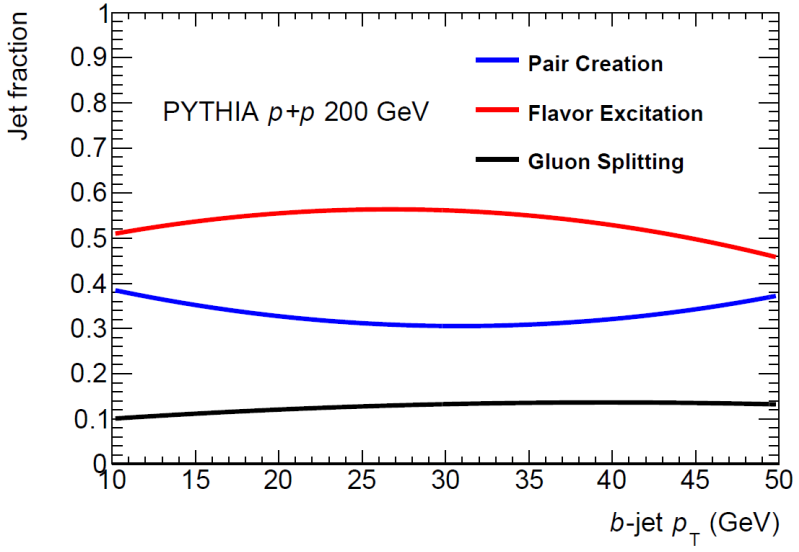
Non-negligible bias in DCAz



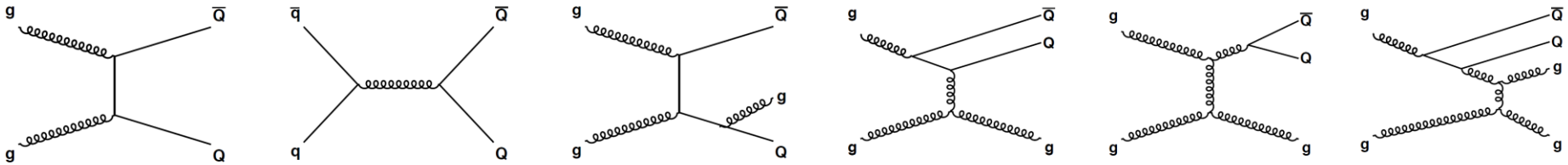
From Haiwang's talk https://indico.bnl.gov/conferenceDisplay.py?confId=1940

b-jet fraction in LUND family estimation



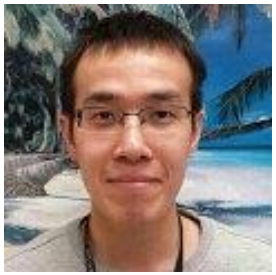


Lund String, Eur. Phys. J. C 17, 137–161 (2000)

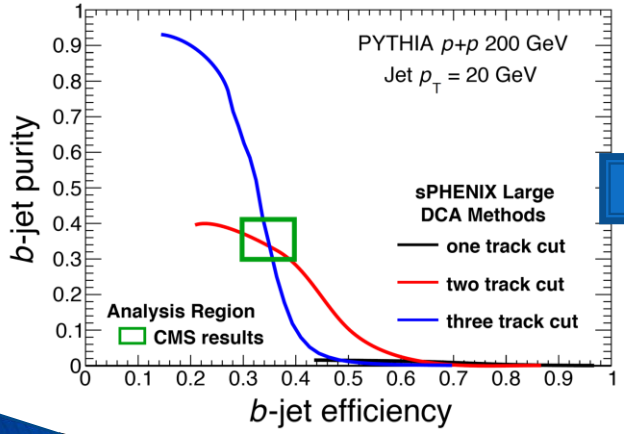


Highlight recent activities:
b-jet tagging – High DCA track counting

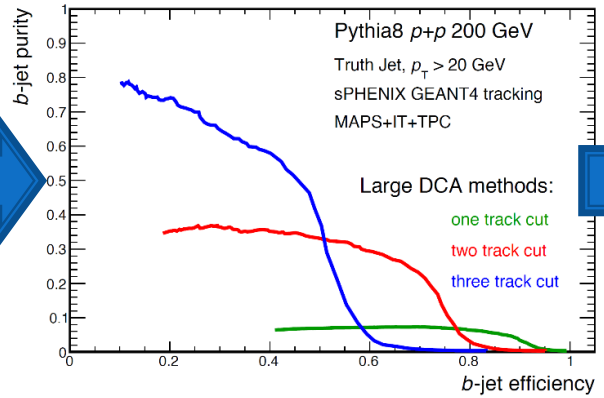
- Progress since last general meeting
  - Dennis and Haiwang implemented track counting tagger in the full Geant4 simulation
  - Haiwang produced projection plot in
- On-going past few weeks
  - Systematically validating the Geant4-based track fit procedure, in order to optimize 3-D DCA and likelihood
- Next
  - Reevaluate in HI background with HIJING embedding
  - Optimizing cuts to suppress fake off-vertex tracks



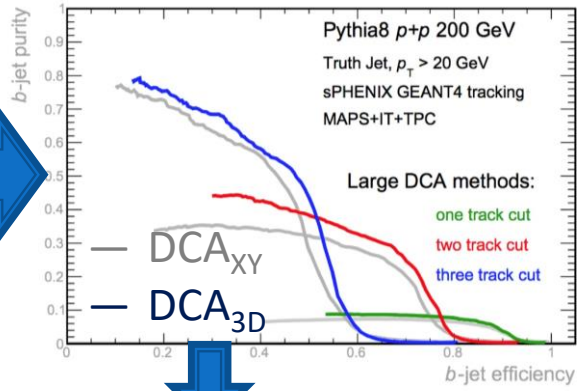
Fast sim in Proposal



Full Geant4 Sim in G4 (DCA_{XY})



Exploring 3-D DCA in G4
NOT optimal tune yet!

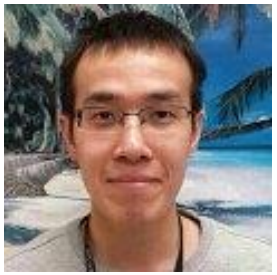


From Haiwang's talk
https://indico.bnl.gov/conferenceDisplay.py?confId=1926

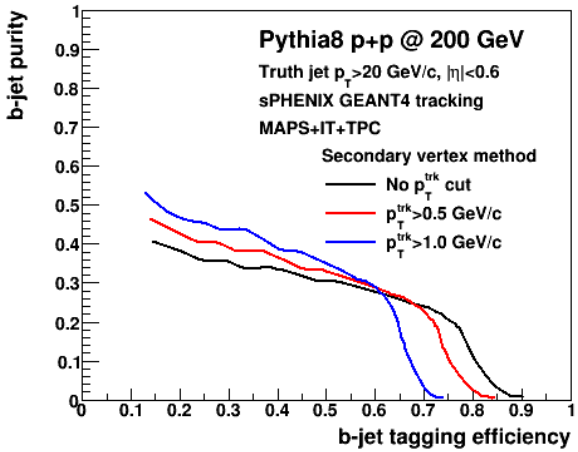
b-tagging performance in HI

Highlight recent activities: *b*-jet tagging – Secondary vertex

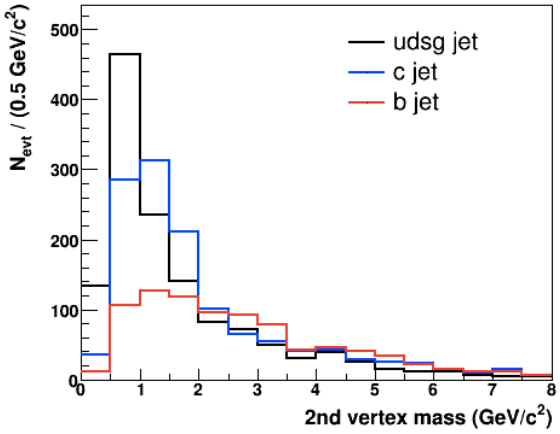
- Progress since last general meeting
  - Haiwang developed new Kalman filter (GenFit2) with vertex finder integration (RAVE)
  - Sanghoon implemented Secondary vertex finder in jet
  - *p+p* performance plot used in tracking review
- Plan next:
  - Reevaluate in HI background with HIJING embedding



Secondary vertex *b*-tagger



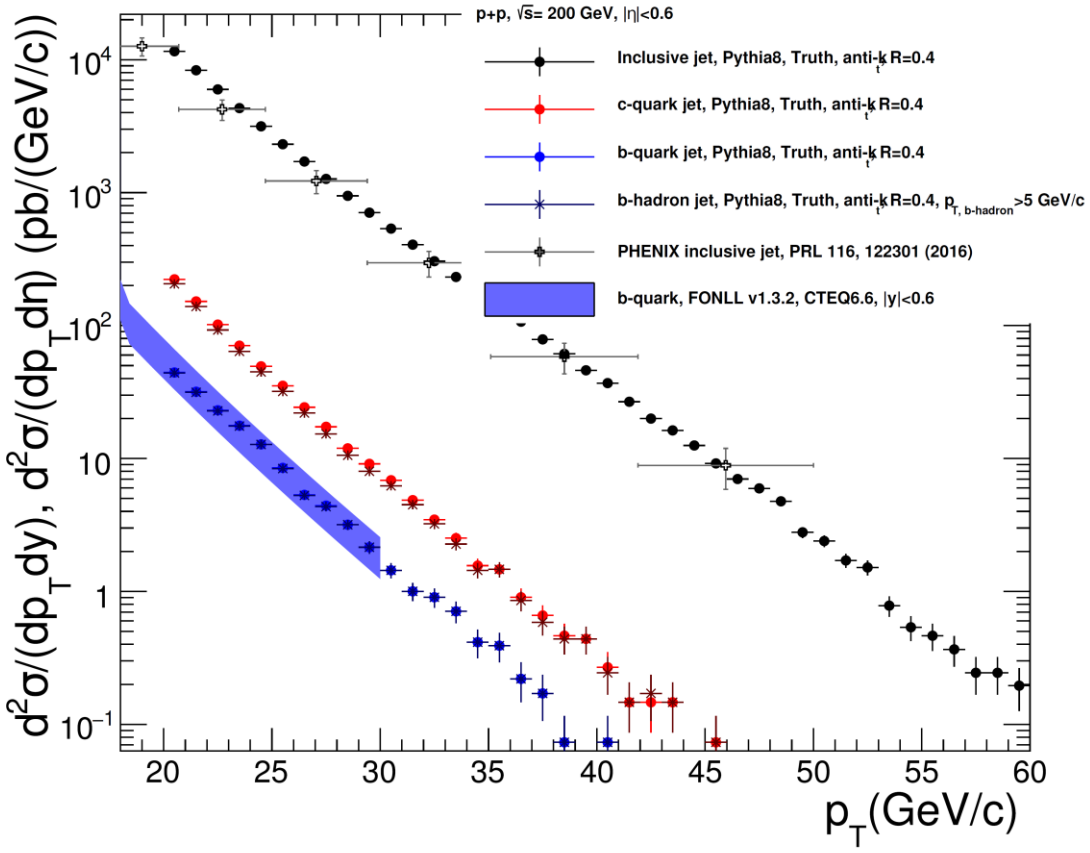
Secondary vertex kinematics fits
Data driven *b*-jet purity estimation



b-tagging performance in HI

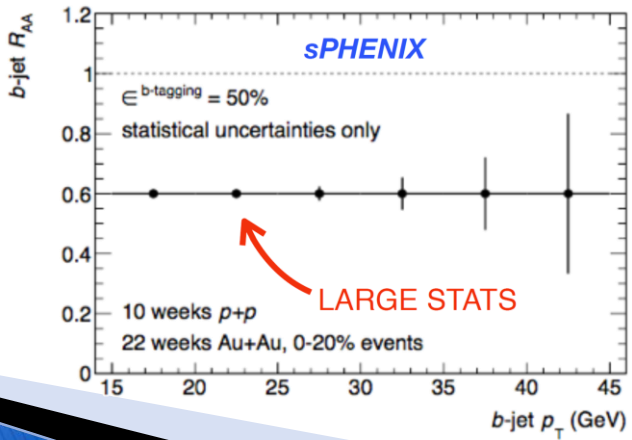
From Sanghoon's talk
https://indico.bnl.gov/conferenceDisplay.py?confId=1928

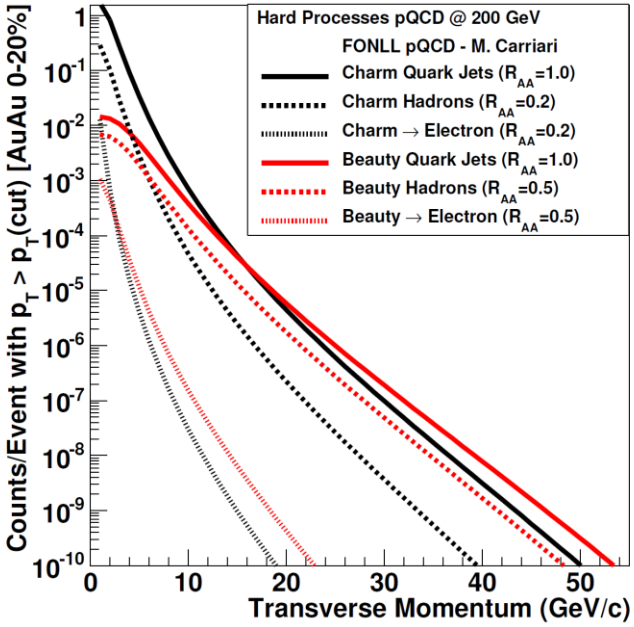
Cross section from pythia8



B-jet tagging – Decay lepton tagging

- None-photonic lepton has been a successful tool in studying heavy quark behavior in QGP
- Given a jet detected, lepton tagging in or near the jet cone could enhance HF jet fraction due to larger fraction of B(->d)->e decay than h->e decays.
  - Benefit:
    - Not necessarily require a DCA capability. No additional sPHENIX detector required
    - (Largely) orthogonal to and cross check life-time-based B tagging: e.g. DCA-track-counting and Secondary vertex mass methods
  - Cost: B->e branching ratio (~20%), electron identification efficiency, (b-tagging efficiency)
- Challenge:
  - Exploring possibility @ RHIC energy
  - Signal/background ratio and
  - Optimization both in $j_{T,e}$ and DCA_e
  - Statistics

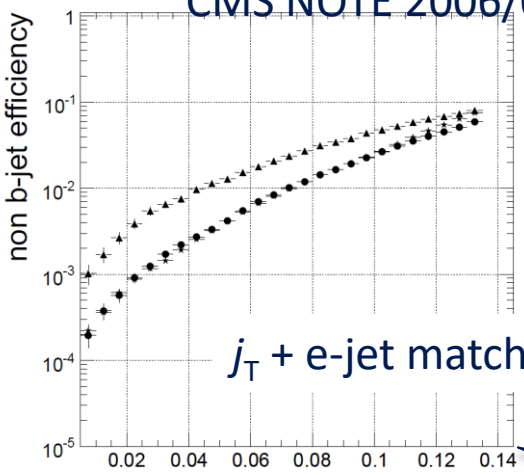




Decay lepton tagging - CMS studies (muon tagging)

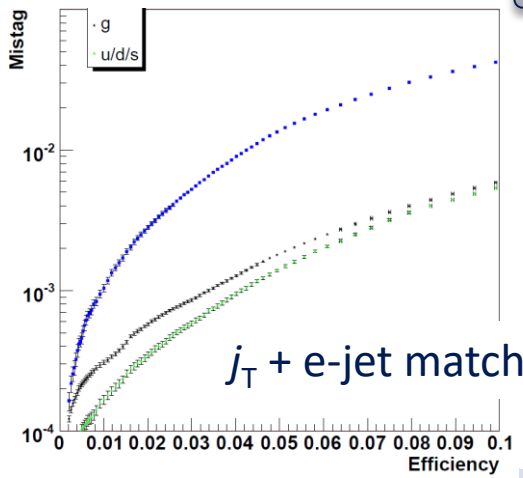
Rejection VS tagging eff.

CMS NOTE 2006/043



j_T + e-jet matching + DCA_e

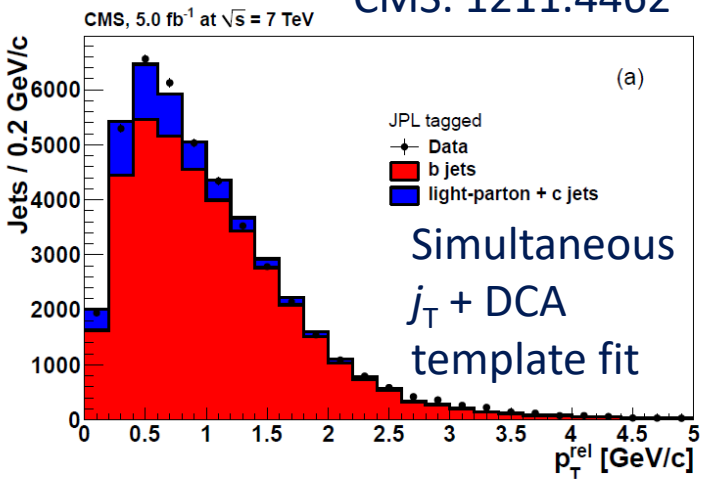
Suffer of B->μ BR

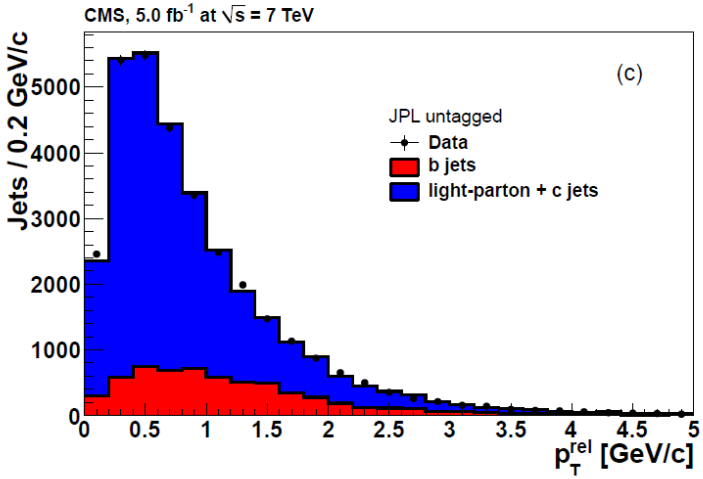


j_T + e-jet matching ~~no DCA_e~~

As cross check to JP/L method

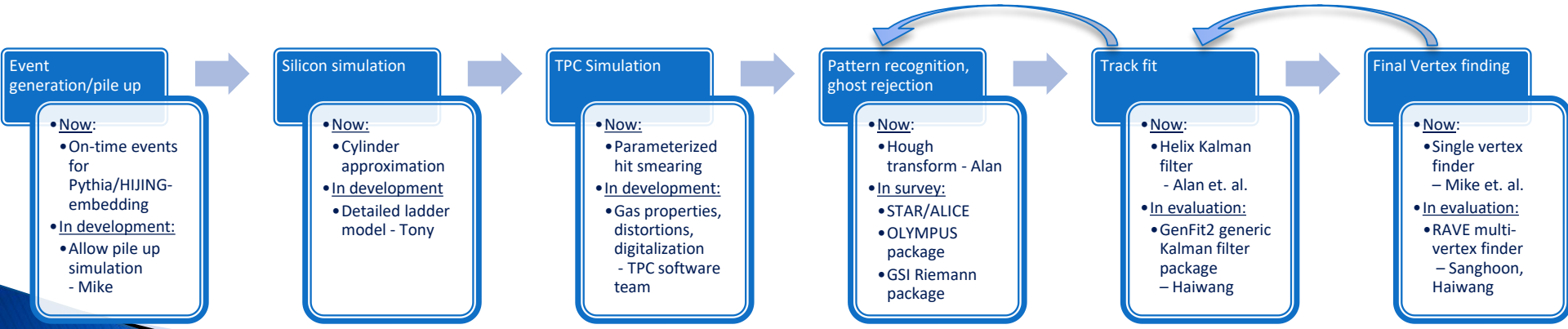
CMS. 1211.4462





sPHENIX tracking simulation and reconstruction chain

- A chain of full detector Geant4 simulation and reconstruction software developed for sPHENIX, used in current detector and physics performance projection
- Limitations in current software that need to be evolved for the next stage
- Many new developments hold back before the Sept-tracking review. Now to be coordinated to be made default.



https://indico.bnl.gov/conferenceDisplay.py?confId=1930